APPENDIX H

TRANSPORTATION ACCIDENT ANALYSIS

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APPENDIX H

TRANSPORTATION ACCIDENT ANALYSIS

H.1 METHODOLOGY

The RADTRAN computer code is used for risk and consequence analysis of radioactive material transportation. The RADTRAN computer code was developed at Sandia National Laboratory in Albuquerque, New Mexico. RADTRAN is used to calculate the dose to transportation workers and persons residing near or sharing transportation links with radioactive materials shipment routes. Exposures may also occur as a result of accidents. Accident-related doses are also computed using the RADTRAN code. The current version used in the Paducah Site ecological assessment is RADTRAN 5 (Neuhauser and Kanipe 2000).

Cargo-Related. Cargo-related accidents are accidents that directly involve the waste being transported. Impact to human populations resulting from cargo-related accidents arises from the radioactivity of the wastes. Radiation doses for population zones (rural, suburban, and urban) are weighted by the accident probabilities to yield accident risk using the RADTRAN 5.2 computer code. Differences in waste types result into different radioactive material characteristics under accident conditions. Characterization data for the representative waste types were developed based on Table 1.1. Transportation accidents are grouped into accident severity categories as described in NUREG/CR-4829 and NUREG-0170. The small percentage of accidents (<1 %) that could result in a breach of the shipping package is represented in a spectrum of accident severities and radioactive release conditions. RADTRAN uses these established severity categories and determines population radiological consequences weighted by the joint probability of 1) accident occurrence and 2) severity.

Radioactive material releases from transportation accidents were calculated by assigning release fractions (the fraction of the radioactivity that could be released in a given severity of accident) to each accident severity. These representative release fractions were identified based on the Idaho high-level waste and Facilities Disposition Draft Environmental Impact Statement. This methodology is consistent with U.S. Department of Energy's (DOE's) methodology for waste-related transportation impact analyses in other environmental impact statements.

Collective doses were then used to determine human health effects in terms of latent cancer fatalities (LCFs) as recommended by the International Commission on Radiological Protection.

Vehicle-Related. Vehicle-related accidents are accidents not related to transportation of waste or materials but simply related to the number of miles traveled by vehicles and the risk of accidents occurring based accident statistics on a per state basis. Mileage through states along a given route were multiplied by state-specific accident and fatality rates to determine the potential numbers of route-specific accidents and fatalities.

H.2 RESULTS

H.2.1 Radiological and Nonradiological Impacts from Routine Truck Transportation of Waste

Radiological Impacts from Routine Highway Transportation. The potential effects of transporting waste by highway from Paducah to each of the potential final destination sites described in Sect. 2.1 were estimated for all three waste subgroups on an annual basis during the major shipment year groupings and on a total 10-year shipping campaign basis. Tables H.1 through H.9 present the estimated risks of shipping the three subgroups of waste to the specified destinations on both annual and 10-year bases for the shipping campaign presented in Table 3.4. The transportation analysis is representative of the various waste types being sent to the specified designations. Therefore, the impacts should not be compared among the various routes, but the overall impact should be evaluated as presented in terms of annual impacts and shipping campaign impacts.

Table H.1. Radiological impacts for truck shipments to Andrews, Texas

	Annual impacts		Total for 10-year life cycle	
Risk Group	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	0.4	1.5E-04	3.7	1.5E-03
Population[a]	0.2	8.5E-05	2.0	1.0E-03
MEI[b] (rem)	3.6E-06	1.8E-09	3.6E-05	1.8E-08

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.2. Radiological impacts for truck shipments to Richland, Washington

	Annual impacts		Total for 10-year life cycle	
Risk Group	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	0.06	2.4E-05	0.6	2.4E-04
Population[a]	0.02	1.0E-05	0.2	1.0E-04
MEI[b] (rem)	2.9E-07	1.0E-05	2.9E-06	1.5E-09

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.3. Radiological impacts for truck shipments to Mercury, Nevada

	Annual impacts		Total for 10-year life cycle	
Risk Group	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	6.1	2.4E-03	61	2.4E-02
Population[a]	2.4	1.2E-03	24	1.2E-02
MEI[b] (rem)	3.4E-00	1.7E-03	3.4E-04	1.7E-07

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.4. Radiological impacts for truck shipments to Clive, Utah

Risk Group	Annual impacts: Dose (person-rem)	Annual impacts: LCF	Total for 10-year life cycle: Dose (person-rem)	Total for 10-year life cycle: LCF
Crew	4.6	1.8E-03	46	1.8E-02
Population[a]	2.1	1.1E-03	21	1.1E-02
MEI[b] (rem)	2.8E-05	1.5E-08	2.8E-04	1.4E-07

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.5. Radiological impacts for truck shipments to Oak Ridge (ETTP), Tennessee

Risk Group	Annual impacts: Dose (person-rem)	Annual impacts: LCF	Total for 10-year life cycle: Dose (person-rem)	Total for 10-year life cycle: LCF
Crew	0.2	8.0E-05	2.0	8.0E-04
Population[a]	0.06	3.0E-05	0.6	3.0E-04
MEI[b] (rem)	4.0E-06	2.0E-09	4.0E-05	2.0E-08

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
ETTP = East Tennessee Technology Park
LCF = latent cancer fatality

Table H.6. Radiological impacts for truck shipments to Oak Ridge (ORNL), Tennessee

Risk Group	Annual impacts: Dose (person-rem)	Annual impacts: LCF	Total for 10-year life cycle: Dose (person-rem)	Total for 10-year life cycle: LCF
Crew	0.008	3.2E-06	0.08	3.2E-05
Population[a]	3.0E-03	1.5E-06	0.03	1.5E-05
MEI[b] (rem)	1.9E-07	9.5E-11	1.9E-06	9.5E-10

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality
ORNL = Oak Ridge National Laboratory

Table H.7. Radiological impacts for truck shipments to Oak Ridge (MEWC), Tennessee

Risk Group	Annual impacts Dose (person-rem)	Annual impacts LCF	Total for 10-year life cycle Dose (person-rem)	Total for 10-year life cycle LCF
Crew	0.05	2.0E-05	0.5	2.0E-04
Population[a]	0.01	5.0E-06	0.14	7.0E-05
MEI[b] (rem)	8.7E-07	4.4E-10	8.7E-06	4.4E-09

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality
MEWC = Materials & Energy/Waste Control Specialists

Table H.8. Cargo-related impacts from truck transportation accidents

Destination	Population risk[a] Dose (person-rem)	Population risk[a] Latent cancer fatalities
Andrews, TX	0.07	3.5E-05
Richland, WA	1.55	7.8E-04
Clive, UT	0.09	4.5E-05
Mercury NV	3.0	1.5 E-03
Oak Ridge (ETTP), TN	.02	1.0E-05
Oak Ridge (ORNL), TN	0.18	9.0E-05
Oak Ridge (MEWC) TN	0.02	1.0E-05
Total	4.9	2.5E-03

[a]Each population risk value is the product of the consequence (population dose or latent cancer fatalities) multiplied by the probability for a range of possible accidents.
ETTP = East Tennessee Technology Park
MEWC = Materials & Energy/Waste Control Specialists
ORNL = Oak Ridge National Laboratory

Table H.9. Estimated fatalities from truck emissions and accidents (vehicle-related impacts)

Destination[a]	Incidents Accidents	Incidents Fatalities	Latent fatalities from emissions[b]
Andrews, TX	6.0E-02	3.1E-03	1.3E-02
Richland, WA	9.0E-03	3.8E-04	2.1E-03
Clive, UT	7.3 E-01	2.7 E-02	1.6E-01
Mercury, NV	1.1 E+00	4.1 E-02	2.6E-01
Oak Ridge (ETTP), TN	1.2 E-02	6.8 E-04	4.2E-03
Oak Ridge (ORNL), TN	5.4 E-04	3.2 E-05	2.0E-04
Oak Ridge (MEWC), TN	2.5 E-03	1.4 E-04	8.8E-04
TOTAL	1.89	0.08	0.43

[a]Accidents and fatalities are based on round-trip distance traveled.
[b]Calculated for travel through urban areas only.
ETTP = East Tennessee Technology Park
MEWC = Materials & Energy/Waste Control Specialists
ORNL = Oak Ridge National Laboratory

Workers and the Public. Dose and risk estimates were modeled using the RADTRAN 5 computer code for dose assessment. The potential exposed populations along these routes are estimated from the route distances and appropriate population densities. This information is derived using the Highway 3.4 computer code for the shortest truck route from Paducah to each of the seven destination sites. The highway code is a routing model that computes population densities along all highway links based on rural, suburban, and urban population groupings.

The estimated risks to the public are proportional to the total number of people potentially exposed to radiation while shipments are in transit. This potentially exposed population is estimated from population density categories and the distance traveled, as described in Sect. 3.10.1. The estimated risks to the public are based on a total dose across all persons within the potentially exposed population.

The differences in estimated risks to the public between destinations are due to differences in the total number of potentially exposed people and do not reflect risks to an individual due to higher dose estimates. Risk estimates are based on risks to a population. For example, the risks of a cancer occurrence due to exposure to radiation from routine (incident-free) shipments of low level radioactive waste (LLW) to Mercury (Nevada Test Site), Nevada, through an average shipping year is 1.2×10^{-3} (less than one within the entire potentially exposed population; see Table C3.4) based on a dose estimate for the entire potentially exposed population along the urban, suburban, and rural routes (Table 3.5). The highest public dose of 24 person-rem for the Mercury (Nevada Test Site), Nevada, destination results in a risk of cancer occurrence of 1.2×10^{-2} (less than one within the entire exposed population; see Table C3.4). The radiological impacts at the various destinations are due primarily to the distance traveled and the number of shipments to each destination rather than any one particular type of shipment.

The estimated risks to workers differ between destinations due to the distance of the destination from Paducah and to the radiological characteristics of the waste forms being transported. The estimated risks from radiation exposure for the trucking crew would be directly proportional to the number of miles traveled, the type of waste, and the number of shipments that were used to estimate the risks for each destination. The estimated highest risk of a cancer occurrence of 2.44×10^{-2} for the entire 10-year shipping period (less than one within the entire crew population; see TableE.9) would occur for the Mercury (Nevada Test Site), Nevada shipping campaign. It is important to note that these estimates are conservative, because it is unlikely that the same trucking crew would be involved over the entire 10-year period. This maximum dose-related cancer occurrence is based primarily on the large number of shipments of LLW. The next highest radiological dose and resultant risk of cancer occurrence for crew members (1.84×10^{-2}; see Table 4.10) is estimated for the Clive (Envirocare), Utah, destination due to the large number of total shipments of radiological polychlorinated biphenyl waste.

Maximally Exposed Individual. The maximally exposed individual (MEI) dose estimates presented in Tables C3.1 through C3.7 demonstrate the relatively small dose a single individual is likely to receive. The MEI dose estimates are also considered extremely conservative since this individual is a hypothetical member of the public who lives 30 m (98 ft) from the highway and would be exposed to every shipment of waste.

Differences between the estimated risks to the MEI between waste subgroups were due to the differences in number of shipments between subgroups and to the differences in risk from the subgroup wastes themselves. The 10-year MEI dose ranged from 1.9×10^{-6} rem for the Oak Ridge (Oad Ridge National Laboratory (ORNL)], Tennessee, destinations to 3.4×10^{-4} rem for the Mercury, Nevada, destination. All MEI dose estimates result in the probability of a LCF of much less than 1.

H.2.2 Radiological and nonradiological impacts from routine rail transportation of waste

The potential effects of transporting LLW, Mixed LLW, and transuranic (TRU) waste by rail from Paducah to the specified potential destinations were estimated for the various subgroups on annual and 10-year shipping campaign bases. As discussed earlier in Chap. 4, a variety of containers would be used to transport the waste. The number of containers per shipment was conservatively doubled for the railcar analysis. Rail shipments would include 55-gal drums, 85-gal drums, ST-90 boxes, B-12 boxes, and B-25 boxes.

Tables C3.10 through C3.16 present the estimated risks of shipping the various waste form subgroups to the specified destinations on annual and 10-year total shipping campaign bases. As for highway transport, shipping campaign estimates were calculated based on shipping waste to the specific destinations and were not analyzed for comparison to various potential destinations; therefore, each of these tables represents radiological impacts to each destination based on the type of waste, number of shipments, and length of rail route to the final destination.

Radiological Impacts from Routine Rail Operations. The estimated risks resulting from incident-free shipments of LLW, MLLW, and TRU waste using rail transportation are presented in Tables H.10 through H.16. These risks were calculated using the same basic methods as the highway analyses. Rail route (Table 3.6) estimates of the potentially exposed populations (Table 3.7) and assumptions for underlying conditions are specific to rail transportation.

Table H.10. Radiological impacts for rail shipments to Hobbs, New Mexico

	Annual impacts		Total for 10-year life cycle	
Risk Group	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	0.2	8.0E-05	1.5	6.0E-04
Population[a]	0.7	3.5E-04	6.8	3.4E-03
MEI[b] (rem)	4.4E-06	2.2E-09	4.4E-05	2.2E-08

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.11. Radiological impacts for rail shipments to Hanford, Washington

	Annual impacts		Total for 10-year life cycle	
Risk group	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	0.02	8.0E-06	0.2	8.0E-05
Population[a]	0.1	5.0E-05	1.1	5.5E-04
MEI[b] (rem)	4.4E-07	2.2E-10	4.4E-06	2.2E-09

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.12. Radiological impacts for rail shipments to Clive, Utah

Risk group	Annual impacts		Total for 10-year life cycle	
	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	1.4	5.6E-04	13.7	5.5E-03
Population[a]	5.7	2.9E-03	57	2.9E-02
MEI[b] (rem)	3.2E-05	1.6E-08	3.2E-04	1.6E-07

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.13. Radiological impacts for rail shipments to Las Vegas, Nevada

Risk Group	Annual impacts		Total for 10-year life cycle	
	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	2.7	1.1E-03	27	1.1E-02
Population[a]	8.1	4.1E-03	81	4.1E-02
MEI[b] (rem)	7.3E-05	3.7E-08	7.3E-04	3.7E-07

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality

Table H.14. Radiological impacts for rail shipments to Oak Ridge (ETTP), Tennessee

Risk group	Annual impacts		Total for 10-year life cycle	
	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	0.1	4.0E-05	1.3	5.2E-04
Population[a]	0.9	4.5E-04	9.2	4.6E-03
MEI[b] (rem)	5.0E-06	2.5E-09	5.0E-05	2.5E-08

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
ETTP = East Tennessee Technology Park
LCF = latent cancer fatality

Table H.15. Radiological impacts for rail shipments to Oak Ridge (ORNL), Tennessee

Risk group	Annual impacts		Total for 10-year life cycle	
	Dose (person-rem)	LCF	Dose (person-rem)	LCF
Crew	0.01	4.0E-06	0.10	4.0E-05
Population[a]	0.04	2.0E-05	0.4	2.0E-04
MEI[b] (rem)	4.4E-07	2.2E-10	4.4E-06	2.2E-09

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality
ORNL = Oak Ridge National Laboratory

Table H.16. Radiological impacts for rail shipments to Oak Ridge (MEWC), Tennessee

Risk group	Annual impacts Dose (person-rem)	Annual impacts LCF	Total for 10-year life cycle Dose (person-rem)	Total for 10-year life cycle LCF
Crew	0.04	1.6E-05	0.35	1.6E-04
Population[a]	0.1	5.0E-05	1.03	5.2E-04
MEI[b] (rem)	1.1E-06	5.5E-10	1.1E-05	5.5E-09

[a]Includes population dose receptors off-link and on-link.
[b]Maximally exposed individual latent cancer fatality represents the probability of a latent cancer fatality occurrence.
LCF = latent cancer fatality
MEWC = Materials & Energy/Waste Control Specialists

Table H.17. Cargo-related impacts from rail transportation accidents

Destination	Population risk[a] Dose (person-rem)	Population risk[a] LCF
Hobbs, NM	0.07	3.5E-05
Hanford, WA	1.74	8.7E-04
Clive, UT	0.07	3.5E-05
Las Vegas, NV	3.2	1.6E-03
Oak Ridge (ETTP), TN	0.09	4.5E-05
Oak Ridge (ORNL), TN	0.4	2.0E-04
Oak Ridge (MEWC), TN	4.4E-02	2.2E-05
Total	5.51	2.8E-03

[a]Each population risk value is the product of the consequence (population dose or latent cancer fatalities) multiplied by the probability for a range of possible accidents.
ETTP = East Tennessee Technology Park
LCF = latent cancer fatality
MEWC = Materials & Energy/Waste Control Specialists
ORNL = Oak Ridge National Laboratory

Table H.18. Estimated fatalities from rail-related accidents

Destination[a]	Incidence Accidents	Incidence Fatalities
Hobbs, NM	4.2 E-03	6.9 E-04
Hanford, WA	9.8 E-04	3.0 E-04
Clive, UT	2.6 E-02	8.6 E-03
Las Vegas, NV	5.1 E-02	1.5 E-02
Oak Ridge (ETTP), TN	1.2 E-03	2.8 E-04
Oak Ridge (ORNL), TN	1.0 E-04	2.3 E-05
Oak Ridge (MEWC), TN	2.5 E-04	5.7 E-05
Total	**0.08**	**0.02**

[a]Accidents and fatalities are based on round-trip distance traveled.
ETTP = East Tennessee Technology Park
MEWC = Materials & Energy/Waste Control Specialists
ORNL = Oak Ridge National Laboratory

Maximally Exposed Individual. The MEI dose estimates presented in Tables E.10 through E.16 demonstrate the relatively low dose a single individual is likely to receive. The MEI dose estimates are also considered extremely conservative, since this individual is a hypothetical member of the public who lives 30 m (98 ft) from the railway and would be exposed to every shipment of waste.

Differences between the estimated risks to the MEI between waste subgroups were due to the differences in the number of shipments between subgroups and to the differences in risk from the subgroup waste itself. For example, the 10-year analysis period for shipment of waste to Oak Ridge (ORNL), Tennessee, results in an MEI dose of 4.4×10^{-6} rem. The MEI dose to the Las Vegas, Nevada, destination for the 10-year period is 7.3×10^{-4}, and the resultant probability of an LCF is minimal at 3.7×10^{-7}.

H.2.2 Risks from rail accidents

Cargo-Related Radiological Impacts. The impacts from the transportation impact analysis are shown in Table C3.17 for cargo-related accident impacts for rail shipments. Each value in the table represents the product of consequence (population dose or LCFs) multiplied by the probability for a range of possible accidents. For rail shipments, the Las Vegas (Nevada Test Site), Nevada, destination would result in the highest doses. This destination results in 3.2 person-rem (1.6×10^{-3} LCF). The total dose and number of LCFs for the entire waste transportation campaign are 5.5 person-rem and 2.8×10^{-3} (less than one LCF), respectively.

Rail-Related Nonradiological Impacts. DOE's analysis of potential rail-related impacts included expected accidents and expected fatalities from accidents. Rail-related accidents are accidents related to the number of miles traveled by rail and to the risk of accidents occurring based on the increase in miles traveled. Mileage through states along a given route was multiplied by state-specific accident and fatality rates to determine the potential numbers of route-specific accidents and fatalities.

As shown in Table C3.18, impacts from rail-related accidents are highest for the Mercury (Nevada Test Site), Nevada, and Clive (Envirocare), Utah, destinations because of the number of shipments and the total miles traveled to and from these destinations.

H.3 REFERENCES

K.S. Neuhauser and F.L. Kanipe, 2000, "RADTRAN 5 User Guide," Transportation Safety and Security Analysis Department, Sandia National Laboratories, Albuquerque, New Mexico.